

thorough knowledge of the inhabitants, whether animal or vegetable, of oceanic islands. The work must be done speedily, or it will be too late; and it is work that can hardly be undertaken on a sufficiently extensive scale without aid from Government.  
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### MICROGRAPHIC ANALYSIS.

**M**ETALLURGISTS would have been greatly astonished if they had been urged at the beginning of the present century to gather information as to the composition of samples of iron and steel by merely looking at polished and etched specimens through a microscope. The operation is, nevertheless, rapidly taking its place in the ordinary routine of a works laboratory.

As regards the history of the development of this new branch of investigation, it appears that micro-metallography has not been developed from petrography. It is the natural extension of the study of meteoric iron, and, as has often happened in the history of science, it seems to have had more than one independent origin. Priority of date rests with our own countryman Dr. Sorby. In 1864 he submitted to the British Association photographs of opaque sections of various kinds of iron and steel, and he endeavoured to develop a method for the industrial examination of such sections under high powers, preferring polished sections to fractured surfaces. The abstract of his paper is very brief; but looking back, it seems strangely comprehensive and suggestive. He claimed that the sections showed "various mixtures of iron, two or three well-defined compounds of iron and carbon, of graphite, and of slag; and these, being present in different proportions, and arranged in various manners, give rise to a large number of varieties of iron and steel differing by well-marked and very striking peculiarities of structure."

Later, Prof. Martens, in Berlin, without neglecting the examination of sections, carefully studied, in 1878, the general laws which govern the occurrence and formation of fractures, fissures, blow-holes, and crystalline structure in metals and alloys. His work, therefore, presents all the characteristics of perfect originality. It was not long after the publication of Martens' work that M. Osmond, then engineer at the Creusot Works, began, with his colleague M. Werth, investigations on the cellular structure of cast steel. This work was published by the *Académie des Sciences* in 1885, and in order to trace the progress which has been made in micro-metallography during the past ten years, it would be difficult to do better than consult the beautiful monograph by M. Osmond which has recently been published by the *Société d'Encouragement* of Paris.<sup>1</sup>

As M. Osmond justly observes, metallography should in its early days be descriptive; it should enable us to determine the form and nature of the various constituents of alloys, to ascertain their mode of distribution, and to measure their dimensions. Later on, when sufficient data have been established, it will be possible to apportion the observed facts to their respective causes (1) by ascertaining the way in which the structure of a given metal changes under the influence of the three combined factors—temperature, time, and pressure, and (2) it will be possible to trace the relations between the observed facts and their consequences by defining the mechanical properties which correspond to a particular structure.

The first step in the complicated procedure is to cut and polish the opaque specimens of steel. The methods do not admit of condensed description, and the original memoir must be consulted, as even the technical manuals of crafts, in which the polishing of metals plays a part,

give but little information that is useful in the preparation of metallic sections for the microscope. It must, however, be added that one method of polishing is specially designed with a view to wear away the softer constituents of the specimen, and bring the harder into relief. It is often useful to attack a polished specimen of steel with a reagent which will colour certain constituents only. For this purpose M. Guillemin treats sections of bronze by oxidation, at regulated temperatures, which produces varied colourations on several constituents of the alloy, while M. G. Charpy prefers an electrolytic attack. It is somewhat surprising to find that an infusion of *coco* (a popular French term for an infusion of liquorice) is very useful for the purpose, which recalls the fact that Japanese artificers have, for centuries, used plum-juice vinegar, decoctions of finely-ground beans (*Glycine hispida*), or extracts of the roots of certain plants, as valuable agents for colouring the peculiar alloys which they employ in art metal-work. It may be that the micro-metallographer has much to learn from the Japanese.

The "attack" of polished specimens is made by suitable reagents, which may be divided into the three classes—acids, halogens, and salts. Of the acids, nitric acid of 36° Baumé appears to be the most useful. Of the halogens the pharmaceutical tincture of iodine gives excellent results, as it removes carbon from the steel, and colours certain portions of the specimen. Such treatment, the nature of which has been so briefly sketched, will serve to reveal the main constituents of steel. These are five in number, and it has been found convenient to give mineralogical names to them, following the suggestion of the distinguished American metallurgist, Mr. Howe. Thus pure iron is called *ferrite*; the carbide of iron,  $\text{Fe}_3\text{C}$ , of Abel, *cementite*. This is not coloured by the infusion of *coco* or tincture of iodine, which latter leaves it of a silver-white brilliancy under vertical illumination. Dilute nitric acid in the cold does not affect *cementite*. The third material is one of the components of the "pearly constituent of Sorby," which may be coloured by *coco* or by iodine, and M. Osmond proposes the name of *sorbite* for it, though he is uncertain as to its exact constitution. The fourth constituent, to which he gives the name of *martensite*, is that which is ordinarily obtained by the rapid cooling of a specimen of steel during the familiar operation known as "hardening." It is a crystalline, fibrous substance which iodine colours readily either yellow, brown or black, according to the amount of carbon it contains. Now, *martensite* preserves its characteristic forms equally well in very low carbon-steels which have been hardened, as well as in high carbon-steels which have been subjected to this process. It may be urged, therefore, that *martensite* is not a carbon-iron compound which has liquated out of the mass, but that it represents the crystalline organisation, formed under the influence of carbon by one of the allotropic forms of iron.

The last of the five constituents of steel, marks the transition of soft iron into hardened steel. The name of *troostite* is after the eminent chemist, and it resembles *sorbite*, but its composition is as yet uncertain. This name is not well chosen, as a variety of silicate of zinc has long been known as *troostite*.

It will be evident that a micro-section of a mass of steel closely resembles a rock-section which has constituent minerals distributed through it. It should, however, be pointed out that there are cases in which the existence of these several constituents cannot be sharply defined, as it is frequently necessary to deal with transition forms which defy classification. *Sorbite*, *troostite*, and *martensite* appear to be solidified solutions of various forms of carbon in diverse forms of iron, for it seems clear that metallographic work on steel brings into prominence the existence of allotropic forms of iron.

In order to realise how complicated the structure of

<sup>1</sup> "Méthode générale pour l'Analyse micrographique des aciers au carbone," par M. F. Osmond (*Bull. de la Soc. d'Encouragement*, vol. x. p. 480, 1895).

ordinary steel really is, reference must be made to some facts recorded in *NATURE*, vol. xli. 1889, p. 32. An attempt was therein made to show that notwithstanding the importance of the part played by carbon in the hardening of steel, the phenomena of hardening cannot be explained solely by a change in the relations of carbon to iron. The iron itself appears to change its state, and M. Osmond has shown that it probably assumes at least three distinct allotropic forms, which he designates respectively as  $\alpha$ ,  $\beta$ , and  $\gamma$  iron.

The fact that the iron itself may exist in more than one state, brings into prominence the causes which under-

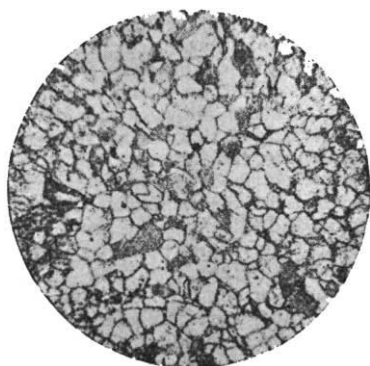


FIG. 1.

lie the difference between an ordinary rock-section and that of a metal or metallic alloy. In granite, for instance, as the fused mass cools the quartz, mica and feldspar fall out of solution in distinct crystalline masses; and although the fusibility of the mass, and consequently its structure, may be greatly influenced by the presence or absence of a small quantity of impurity, say two or three per cent. of sodium, still, so far as we know, complications do not arise from allotropy of the constituent elements of the rock. In the case of a specimen of carburised iron the conditions are widely different. It is certain that one very vital change in the relations between the



FIG. 2.

carbon and the iron does actually take place at  $650^{\circ}\text{C}$ ., that is to say, at a temperature far below the fusing point of the mass. The decomposition of the carbide of iron,  $\text{Fe}_3\text{C}$ , may take place at various rates. Cementite can, for example, under sufficient pressure, resist decomposition at a temperature well above that at which it would ordinarily decompose, and we are confronted with the complications which ensue when carbon is united, not merely with  $\alpha$  iron, but with  $\beta$  or  $\gamma$  iron, so as to form either  $\text{Fe}\beta^3\text{C}$  or  $\text{Fe}\gamma^3\text{C}$ .

A few examples will serve to make the method of investigation clear. The effect of annealing steel is very

remarkable. The operation consists in raising the metal to a high temperature and in allowing it to cool slowly. A granular structure is thus developed in the metal, the size of the polyhedral grains being proportional to the temperature to which the metal is raised. If the temperature is over  $1000^{\circ}\text{C}$ . the grains of ferrite (iron) will be large, while the perlite remains outside the grains and arranges itself in the joints round them. Fig. 1 represents a sample of very mild steel containing 0.14 per cent. of carbon which had been forged and etched with dilute nitric acid; while Fig. 2 represents the same steel which has been cooled from an initial temperature of  $1015^{\circ}\text{C}$ .

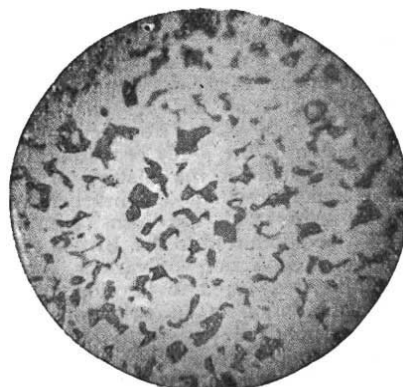


FIG. 3.

In it the ferrite has arranged itself in larger grains than was the case in the first section, which had not been raised to nearly so high a temperature before cooling. Now compare this with Fig. 3, which shows the effect of raising the steel to an initial temperature of  $960^{\circ}\text{C}$ ., allowing it to cool down to a temperature of  $770^{\circ}\text{C}$ ., and then cooling it rapidly by quenching it in water. Microscopic examination shows that the interstitial matter is martensite, together with some troostite, while the principal mass is still ferrite in grains. These three specimens, chosen, it should be remarked, from the eighty-five beautiful photographs given



FIG. 4.

by M. Osmond, serve to show how much the structure of the same variety of steel will vary with the thermal treatment to which the metal has been subjected. Fig. 4 shows a sample of more highly carburised steel polished with rouge, which presents a vermicular surface of ferrite and perlite.

There would appear to be no limit to the applications of micrographic analysis, as all metals and all alloys may be subjected to its action. It is known, for instance, that the qualities of the copper alloys are greatly modified by the addition of minute quantities of deoxidising agents, such as phosphorus, aluminium, or silicon, and

M. Guillemin, in an admirable paper on the metallography of the alloys of copper presented to the French "Commission des Méthodes d'essai des Matériaux de Construction,"<sup>1</sup> has given evidence that it is possible to pronounce with certainty, by the examination of etched surfaces of examples of the alloys, which deoxidiser has been employed.

It remains to be seen in what way the mechanical properties of steel are connected with the structural changes revealed by micrographic examination. In every specimen of steel, as has already been stated, at least three great molecular changes are produced as the metal is raised from the ordinary temperature to a white heat. The belief that the rearrangement of atoms in the molecule of iron (which is, in fact, allotropy) is really fundamental to these molecular changes, is rapidly gaining adherents, but authorities on hardening of steel are by no means in accord as to the true significance of allotropy in relation to that important industrial operation. The writer of this paper has long declared himself to be a pronounced allotropist, and many patient experimenters are hard at work at the problem. M. Charpy,<sup>2</sup> for instance, had already pointed to the peculiar behaviour of steel under longitudinal stress, as proof that the metal undergoes allotropic change. He now seeks, by an elaborate series of experiments, to ascertain whether the mechanical tests of steel which has been quenched at definite temperatures, support Osmond's view as to the significance of the part played by allotropy of iron in the hardening of steel. Charpy's opinion seems to be that, on the whole, his experiments do not afford conclusive evidence in support of Osmond's view. It may, however, be urged that in the case of steel, mechanical tests could not be expected to afford decisive evidence in relation to the theoretical significance of allotropy, because, as M. Osmond's micrographic work shows, the structure of steel is so complex and varies so much with thermal treatment. It is, of course, ultimate structure which determines the strength and elasticity of steel, and none of us claim that allotropy is the sole factor in the production of structure.

The magnetic behaviour of steel, on the other hand, as M. Curie has recently pointed out, is greatly influenced by temperature, for, within the range of 20° to 1350°, rapid variations in magnetic properties of soft iron reveal themselves at about 750°, 860°, and 1280°. This, as he says, is favourable to the views of M. Osmond, because on independent evidence we are led to conclude that at temperatures near these points the metal undergoes allotropic modifications.

It is to be hoped that microscopic analysis will soon take its place in the ordinary routine of every steel works laboratory, and it should be added that in this country two well-known authorities, Mr. T. Andrews and Mr. J. E. Stead, constantly employ it, while Mr. A. Sauveur<sup>3</sup> has originated the system already in the works of the Illinois Steel Company. W. C. ROBERTS-AUSTEN.

#### THE SCIENTIFIC RESULTS OF THE ANNUAL MEETING OF THE BRITISH MEDICAL ASSOCIATION.

THE annual meeting of the British Medical Association is, no doubt, increasing in importance, since it is becoming a congress for the demonstration of the advance of medicine. The work of the meeting may be considered as belonging to two classes, the practical and the scientific. Many, no doubt, who attend the annual meeting, do so with the object of gaining practical help

in both the medical and the surgical treatment of their patients; and this help the annual meeting gives in abundance. One of the most important parts of the meeting, however, is that which is occupied with the progress of scientific medicine, and consists not so much in the announcement of startling discoveries (for with these medicine has but little to do), but in the revision and criticism of the facts discovered by experiment and at the bedside.

Medical science is becoming more exact, as the knowledge of the functions of living tissues (physiology) and their changes in disease (pathology) increases.

It is not so many years ago when the chief subject in what was called physiology was histology, or the structure of the tissues. Physiology proper then rapidly progressed, and although at first it was considered from a somewhat too physical standpoint, and indeed is still so considered by some, yet it has received an enormous impetus by being associated with the study of chemistry and of the action of the chemical constituents of the body on the living tissues. This is evidenced in the excellent address on "Internal Secretion," given by Prof. E. A. Schäfer, F.R.S., of University College, a subject which in its scientific aspects is of a quite recent development. A secretory organ may, like the stomach, salivary glands, &c., separate materials from the blood and pour them into a cavity, in which they are utilised; this may be called external secretion. On the other hand, "some secreted materials are not poured out upon an external surface at all, but are returned to the blood"; these may be called internal secretions. Although it is probable that in the widest sense every tissue has an internal secretion, yet this is most obvious in the ductless glands, such as the thyroid, the suprarenal bodies, and the pituitary body. But in one gland with an important external secretion, viz. the pancreas, there is also an internal secretion which is of great value in the economy.

The subject of internal secretion has developed hand in hand with clinical medicine, and it was the observation of patients which first, as in the case of the thyroid, gave the clue to the line of investigation. It is impossible in this place to give a detailed account of Prof. Schäfer's address; it is well worthy of study by every one interested in the progress of biological science. It will not be out of place, however, to illustrate the subject of internal secretion by quoting as examples the investigation of the pancreas and the suprarenal capsules, the latter of which has been the subject of special study by Prof. Schäfer, in conjunction with Dr. G. Oliver and Mr. Moore.

The association of disease of the pancreas with the presence of sugar in the urine has long been noted; although only a certain proportion of cases of diabetes show any great changes in this organ. If the pancreatic juice be diverted from the intestine, or if the duct be blocked, the animal experimented upon does not die, there is no glycosuria, nor does it apparently suffer any great nutritional change. If, however, the pancreas be totally extirpated, glycosuria appears, and the animal invariably dies; this does not occur, however, if only a part of the organ be removed. More than this, if a portion of living pancreas be successfully grafted into an animal from which the organ is subsequently completely removed, no evil results follow. Besides its obvious and important function of secreting a digestive juice, the pancreas therefore produces some material which it gives to the blood, and which is essential for the continuance of life; this is the internal secretion. On the other hand, it is suggested that the organ nominally separates and transforms some toxic substance which is fatal to existence; this is the theory of auto-intoxication. The internal secretion of the suprarenal capsule is more obvious, perhaps, than that of the pancreas. The capsule is a ductless gland; it has no external secretion. The complete

<sup>1</sup> "Analyse Micrographique des Alliages." (*Comptes rendus*, vol. cxv. p. 232, July 25, 1892.)

<sup>2</sup> "Bull. de la Soc. d'Encouragement," vol. x. 1895, p. 660.

<sup>3</sup> "Trans. Amer. Soc. Mining Engineers," vol. xxii. p. 546.